Available online at www.sciencedirect.com
SciVerse ScienceDirect
ELSEVIER
Procedia CIRP 6 (2013) 53 – 57
www.elsevier.com/locate/procedia

The Seventeenth CIRP Conference on Electro Physical and Chemical Machining (ISEM)

Development of strip EDM

K.Y. Song[a], D.K. Chung[b], M.S. Park[c], C.N. Chu[a,]*

[a]Seoul National University, 1 Kwanak-no Kwanak-gu, Seoul and 151-742, South Korea
[b]Dong Yang Mirea University, 445 Gyeongin-ro Guro-gu, Seoul and 152-714, South Korea
[c]Seoul National University of Science and Technology, 232 Gongneung-ro Nowon-gu, Seoul and 139-743, South Korea
* Corresponding author. Tel.: +82-2-880-7147; fax: +82-2-887-7259.*E-mail address*: cnchu@snu.ac.kr.

Abstract

Electrical discharge machining (EDM) is a widespread machining method for the die and mold industry. This method can machine all conductive materials, including hard-to-cut metals, because the machining process uses electro-thermal energy without a cutting force. During EDM, discharge sparks remove not only the material of a workpiece but also the material of an electrode. This machining mechanism thereby causes electrode wear, which creates serious problems, including make-shape errors and low productivity. In order to overcome such problems, a new EDM method using a strip electrode (strip EDM) was developed in this study. Strip EDM uses a continuously applied strip electrode similar to the wire electrode in wire EDM. In the suggested strip-electrode method, a conductive strip moves on the electrode guide. The worn strip is removed, and a new one is supplied continuously. Therefore, the tool electrode acquires no wear during the machining process. This method uses a conductive strip that is made of brass. In the practical machining process, the strip EDM method was applied to EDM milling and EDM turning and their machining characteristics were compared with general EDM methods.

Selection and/or peer-review under responsibility of Professor Bert Lauwers

Keywords: EDM; Electrode Wear; Strip Electrode; Milling; Turning

1. Introduction

Electrical discharge machining (EDM) can deal with all conductive materials regardless of their mechanical properties, such as strength and hardness. This machining method uses electrical discharge sparks between a tool electrode and a workpiece. The sparks mainly remove the materials of the workpiece, but the electrode also causes damage through the high temperature of the discharge sparks. The damage caused by the electrode is known as electrode wear [1, 2]. There are several kinds of EDM methods: die-sinking EDM, wire EDM, electrical discharge drilling, etc. All of these processes result in electrode wear. The tool electrode wear of the EDM process causes shape errors on the machined portion of a workpiece. To overcome the wear problem, generally two methods are adopted. The first is a compensation tool path in which a tool electrode moves down the worn length and the electrode follows the tool path during the machining process [3, 4]. However, this method cannot compensate for the side wear of the electrode. Moreover, it is difficult to predict wear because of the non-uniform deformation of the tool electrode. The second method is a finishing or skimming cut with new electrodes. After the rough-cut process with high energy, the finish-cut processes are carried out with a small amount of discharge energy, and new electrodes are used in each step [5, 6]. Although this method is practical and widely used, electrode wear also occurs in the finish-cut process, and there are clamping errors when the worn tool electrode is changed for a new one. This study proposes a strip electrode and guide system to overcome the electrode-wear problem during the EDM process. The strip EDM method is a combination of EDM milling and wire EDM. It not only prevents electrode wear but also does not need tool path compensation or new electrodes for the finish-cut process. Considering these advantages, for this paper, the strip EDM method was applied to EDM milling and turning in order to machine various stainless steel workpieces.

2212-8271
Selection and/or peer-review under responsibility of Professor Bert Lauwers
doi:10.1016/j.procir.2013.03.012

2. Strip-EDM system

2.1. The concept of strip EDM

In the general EDM process, electrode wear begins from the surface of an electrode. The wear increases along the tool path and the electrode shape becomes deformed, as shown Fig. 1(a). On the other hand, the strip EDM process changes the continuously worn surface to a new one by feeding a strip electrode, as shown in Figs. 1(b) and (c). The thin strip rolls like the surface of an electrode and moves in the same way as the wire EDM process or wire electro-discharge grinding [7]. Therefore, this machining method does not result in electrode deformation or wear.

2.2. Strip electrode apparatus

Figure 2 shows the strip electrode apparatus designed for this study. The strip electrode was wound in a bobbin and moved via an electrode guide through several guide rollers and side guides. The tip of the electrode guide is round with a 5 mm radius. Therefore, the strip could slide smoothly on the surface of the guide. During the machining process, the winding reel withdrew the strip that was worn by the discharge sparks.

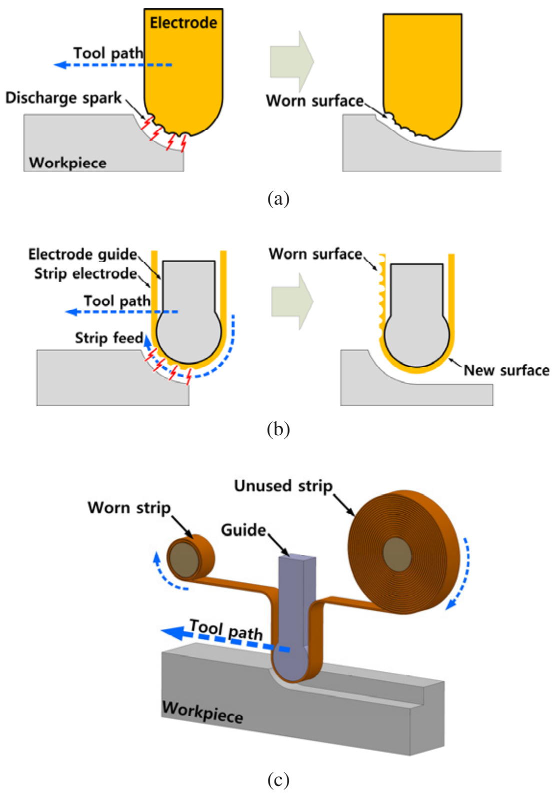


Fig. 1. (a) General EDM; (b) Strip EDM; (c) The concept of the strip EDM.

3. Experimental set-up

3.1. Machining conditions

A commercial wire EDM machine (EZ20S, SPM Co., Ltd.) was used in this study. As shown in Fig. 2, the strip electrode apparatus was set on the Z-column of the machine and could move relatively to the workpiece. The power source generated bipolar pulses that consisted of +140 V and -80 V as shown in Fig 3. The pulse conditions were 12.8 kHz with a duty ratio of 36%. The working fluid was deionized water, and a nozzle injected it into a machining gap. Although water causes corrosion of a workpiece during the EDM process, the bipolar pulse could prevent the problem due to the low average voltage between the workpiece and the electrode [8, 9]. The strip electrode was made of brass, and its thickness and width were 0.1 mm and 10 mm, respectively. When the strip slid on the electrode guide, its speed was 2 mm/s that was the minimum feed speed of the strip feed system. Experimentally, the machining characteristics did not vary according to strip feed speed. Therefore, that feed speed was selected to economize on electrode material from a practical point of view. The machining conditions used in this study are listed in Table 1.

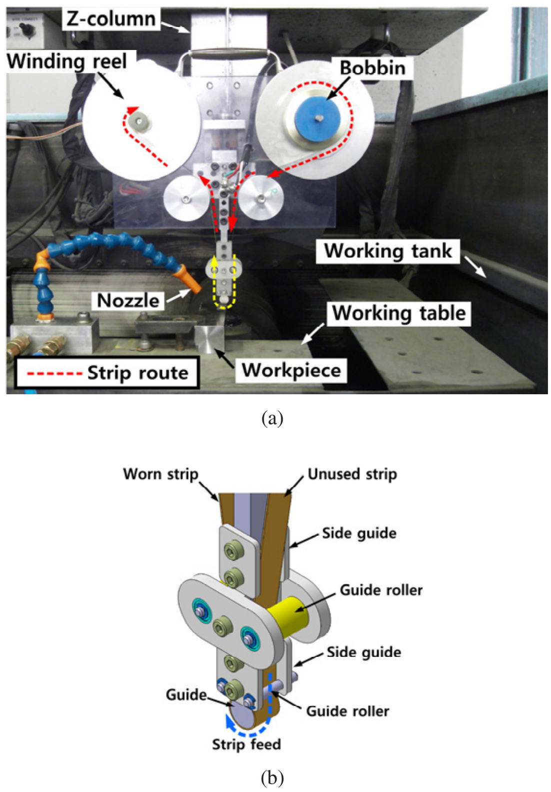


Fig. 2. (a) Strip-EDM system; (b) Electrode guide.

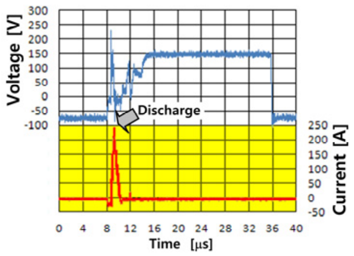


Fig. 3. Voltage and current waveforms during machining.

Table 1. The machining conditions.

Electrode	Brass strip Width: 10 mm Thickness: 0.1 mm
Workpiece	Stainless steel 304
Working fluid	Deionized water
Open-gap voltage	-80 V, +140 V
Peak current	240 A
Frequency	12.8 kHz
Duty ratio	36%

3.2. EDM milling

Figure 4 shows the schematics of the EDM milling in this study. To compare the strip method with the use of a block electrode, the same machining conditions of the strip EDM were used. The depth of the cut and machining length were 1 mm and 15 mm, respectively. The material of the block electrode was brass, the same as the strip.

3.3. EDM turning

The strip-EDM turning was compared to wire-EDM turning when the radial depth of the cut was 0.5 mm. The diameter of the rod workpiece was 3 mm. In the wire-EDM turning, the length of the cut was 10 mm, which was the same as the width of the strip electrode. The wire electrode moved in the axial direction of the workpiece rod, as shown in Fig. 5(a). On the other hand, the strip electrode moved in the radial direction of the rod in the strip-EDM turning process. Figure 5(b) shows a schematic of the strip-EDM turning. This machining process consisted of two steps, as shown in Fig. 5(c). In the first step, the electrode machined a rod with no rotation. Secondly, the rod began to rotate when the electrode reached the center of the rod. The machining process finished when the workpiece completed a single rotation. The wire-EDM turning should rotate the workpiece at a high speed because this machining method could make a helical shape on low rotation speed [10, 11]. The workpiece rod rotated at 90 rpm in the wire-EDM turning process. However, the strip-EDM method was able to complete the machining with only one revolution.

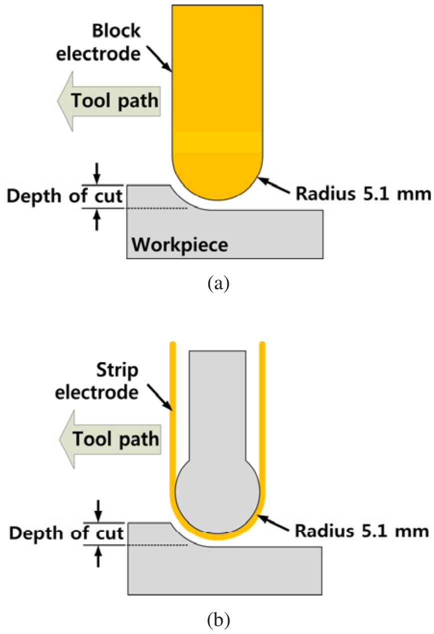


Fig. 4. (a) Normal EDM milling using a block electrode; (b) Strip-EDM milling.

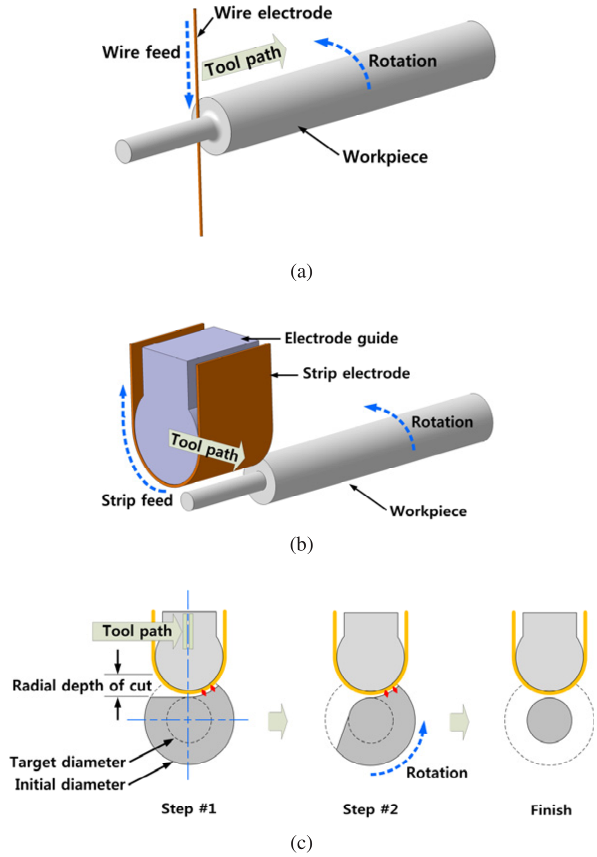
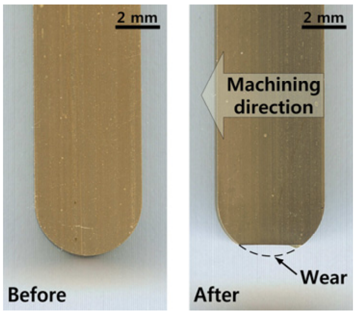
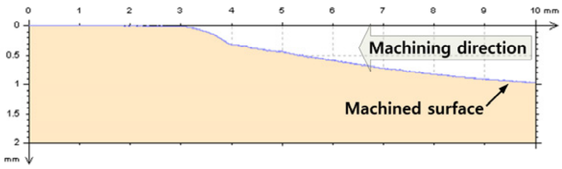


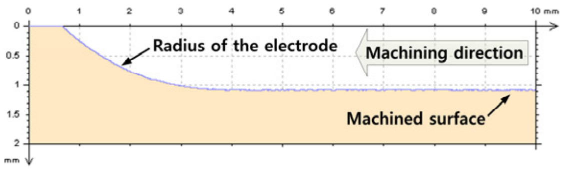
Fig. 5. (a) Wire-EDM turning; (b) Strip-EDM turning; (c) Steps of strip-EDM turning.



(a)



(b)



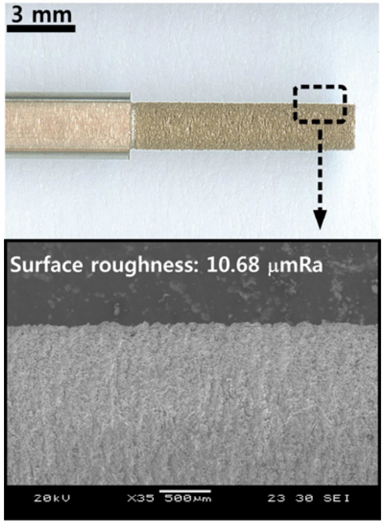
(c)

Fig. 6. (a) The block electrode before and after machining; (b) The profile of the machined surface using a block electrode; (c) The profile of the machined surface using a strip electrode.

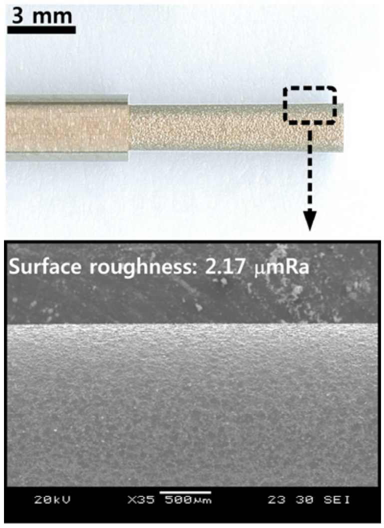
4. Results and discussion

4.1. EDM milling

In the EDM milling experiments, the strip-EDM milling method was compared to a general method using a block electrode. Figure 6(a) shows the electrode that was used before and after machining. Electrode wear occurred during the machining process, and the wear brought a shape error on the machined portion, as shown in Fig. 6(b). The bottom of the machined groove tilted because the electrode was gradually worn as it followed the tool path. On the other hand, the strip-EDM milling did not cause a shape error because the strip method did not involve electrode wear during the machining process. Figure 6(c) shows the profile of the machined groove using the strip-EDM milling method. The material removal rate (MRR) of strip-electrode method was higher than that of the wire EDM method: MRR of the strip EDM was 15.9 mm^3/min, while the use of the block electrode had an MRR of 9.6 mm^3/min. In case of the block electrode, the machined volume was decreasing due to deformation of the electrode during machining. That caused the reduction of MRR. The machined surface had roughness of 1.82 µmRa in strip electrode and 2.47 µmRa in the use of block electrode.



(a)



(b)

Fig. 7. (a) The shaft machined by a wire-EDM turning; (b) The shaft machined by a strip-EDM turning.

4.2. EDM turning

Figure 7 shows the workpiece rods machined by wire-EDM turning and strip-EDM turning, respectively. When the wire electrode was used, the machined surface was rough due to cusp. On the other hand, the surface machined by strip-EDM turning was smooth and had no cusp because the machining portion of the strip electrode was flat. The values of the surface roughness were 10.68 µmRa in the wire-EDM turning and 2.17 µmRa in the strip-EDM turning, respectively.

MRR of the strip method was higher than that of the wire-EDM method: the strip EDM MRR was 12.24 mm^3/min, while the wire EDM had an MRR of 6.50 mm^3/min. The wire electrode had a small machining area due to the small diameter of the wire electrode, but the strip electrode had a larger machining area than the wire. Therefore the machining speed of the strip-EDM turning could increase under the same machining conditions.

5. Conclusions

In this paper, a strip-EDM method was proposed to overcome tool-electrode wear during the EDM process. The strip-electrode method also applied to EDM milling and EDM turning. The following conclusions were drawn:

(1) In the EDM milling process, the general method using a block electrode caused a shape error due to electrode wear during machining, but the strip-EDM milling did not present this problem. The proposed machining method was not concerned with wear and therefore there was no shape error on the machined part.

(2) In the EDM turning process, wire EDM is widely used because it does not cause electrode wear; however, it generates cusp on the machined surface and a low MRR due to the small diameter of the wire electrode. In the case of strip-EDM turning, the flat electrode did not produce a cusp, and the large area of the strip increased the MRR.

As a result, the strip-EDM process could machine various shapes on stainless steel workpieces without generating tool-electrode problems.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by Korea government (MEST) (No. 2012-0000348).

References

[1] Kozak, J., Ivanov, A., Al-naemi. F., Gulbinowicz, Z., 2007, “EDM Electrode Wear and its Effect on Processes Accuracy and Process Modeling,” 15th International Symposium on Electromachining, Pittsburgh, U.S.A., p. 81.

[2] Jameson, E., C., 2001, “Electrical Discharge Machining,” Society of Manufacturing Engineers, Dearborn, p. 180.

[3] Bleys, P., Kruth, J., P., Lauwers, B., Zyd, A., Delpreti, R., Tricarico, C., 2002, “Real-time Tool Wear Compensation in Milling EDM,” Annals of CIRP – Manufacturing Technology, 51, p. 157.

[4] Yuan, R., Wei, B., Luo, Y., Zhan, Y., Xu, W., Lamphere, M., 2007, “High-Speed Electroerosion Milling of Superalloys,” 15th International Symposium on Electromachining, Pittsburgh, U.S.A., p. 207.

[5] Saito, N., Mori, N., Takawashi, T., Furoya, M., 1997, “EDM Technology,” Nikkan Kogyo Shimbun Ltd., Tokyo, p. 66.

[6] Manabe, A., Haishi, Y., 1997, “Die-sinking EDM,” Nikkan Kogyo Shimbun Ltd., Tokyo, p. 32.

[7] Masuzawa, T., Fujino, M., Kobayashi, K. 1985, “Wire Electro-discharge Grinding for Micro-machining,” Annals of CIRP – Manufacturing Technology, 34, p. 431.

[8] Chung, D. K., Shin, H. S., Park, M., S., Chu, C., N., 2011, “Machining Characteristics of Micro EDM in Water Using High Frequency Bipolar Pulse,” International Journal of Precision Engineering and Manufacturing, 12, p. 195.

[9] Chung, D., K., Shin, H., S., Chu, C., N., 2012, “Modeling and Experimental Investigation for Electrolytic Corrosion Prevention in High Frequency Micro EDM Using Deionized Water,” Microsystem Technologies, 18, p. 703.

[10] Imai, T., Suzuki, T., Kwatsu, H., Koto, A., 2010. “Electrical Discharge Machining,” Gijutsu-Hyohron Co., Ltd., Tokyo, p. 124.

[11] Song, K. Y., Chung, D. K., Park, M. S., Chu, C. N., “Strip-EDM Turning,” 2012, Proceeding of Korean Society for Precision Engineering Autumn Conference, p. 41.